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Influence Study on Electromagnetic Flow Meter with Oil Bubble in the Fluid *

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Abstract

electromagnetic flow meters are widely used in two-phase flow measurement of oil-water in recent years. Simulation model is established to study the electromagnetic flow meter response characteristic to two-phase flow of oil-water in cross section by using finite element software ANSYS. Especially, we have analyzed the impact of electromagnetic flow meter with different sizes and positions of oil bubble in the cross-section of flow meter measuring area. Which provide reference for measurement of electromagnetic flow meter in two-phase flow of oil-water. It is basic work for precise measuring of electromagnetic flow meter.

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Keywords: electromagnetic flow meter, Simulation, ANSYS, Oil bubble.

1 Introduction

Electromagnetic flow meter is an important flow measuring instrument with a wide range of applications. Electromagnetic flow meter has unique advantages when used in multi-phase flow, like no sense to velocity distribution and no flow-impeding parts in pipeline[1], but the basic theory about this instrument is based on single-phase flow. In recent years, electromagnetic flow meter is widely used to measure two-phase flow of oil water. When it use to measure two-phase flow of oil water, the distribution of its electromotive force will be changed with oil bubble appears, and deviation will consequently be brought to the measurement. Therefore, it is necessary to analysis electromagnetic flow meter's response characteristic to the oil bubbles. Xiaozhang Zhang has solved the distribution of virtual current with a single bubble at axis and different position of the cross-section by using a simplified two-dimensional mode[2 3], and made a study of 3D features of the electromagnetic flow meter's virtual current in single

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bubble situation[4]. Jae-EunCha used two flow meters to calculate the size of the void fraction [5], Yueming Wang made a study on the Effect of virtual current distribution in an electromagnetic flow meter with oil bubble at axis[6]. In this paper, simulation model has been built about the response characteristic of an electromagnetic flow meter with oil bubbles in different sizes and same size but different positions by using Finite element software ANSYS, and then data analysis has been done under the model so that we could make a study on effect of electromagnetic flow meter by oil bubble in different sizes and positions by the sensitivity of virtual current. The result provided a reference for electromotive measurement in two-phase flow of oil-water.

2 Study on Sensitivity Impact of Sensitive Field

The basic equation of electromagnetic flow meter

$$U = \int_A \vec{W} \bullet \vec{V} dA \tag{1}$$

Where:U is electrical potential between two poles; A stands for all space integral; W is vector weight function, It is an quantity determined only by the structure of electromagnetic flow meter itself. The expression is:

$$\vec{W} = \vec{B} \times \vec{j} \tag{2}$$

Where, $\vec{j}$ is virtual current density, which is a quantity totally determined by boundary condition of A. Virtual current is a significant quantity electromagnetic flow meter theory. It determines the distribution of weight function in measuring area, and so it determines the distribution of sensitive field.

When oil bubble emerges in fluid, the distribution of the virtual current will change. In order to evaluate the effects of oil bubbles on the virtual current distribution, c is defined as Sensitivity as (3) follows:

$$c = \frac{\iint_A \left| j_x - j_x^0 \right| dA}{\iint_A \left| j_x^0 \right| dA} \tag{3}$$

Where, j_x stands for a component of virtual current in direction x under the condition of oil bubble exist in fluid(x direction is the direction of electrode). j_x^0 stands for a component of virtual current in direction x with oil bubble doesn't exist in fluid, and A is the effective space.

3 Analysis that Different Sizes of Oil Bubbles Impact on Flowmeter

In this simulation experiment, the radius of cross section of electromagnetic flow meter measuring area is R, and an oil bubble exists inside fluid of flow meter. Seting the oil bubble diameters of 0.1R, 0.2R, 0.4R, 0.6R, 0.8R, we carry on a simulation analysis with those bubbles that how it impact on virtual current in electromagnetic flow meter measuring area.

As simulation model shown in Figure 1, through the center of the electrode is Y-axis and through the center of the core is X-axis which constitutes the Cartesian coordinate system. The oil bubble locates in the center of measuring area. The certain voltage values are given to electrode ends. Then, the distribution of virtual currents in fluid is shown. In order to get c of sensitivity with different sizes oil bubble exists in the fluid. We have done a lot of simulations. Figure 2 shows the distribution of the virtual current in x direction in the ANSYS simulation when the diameter of oil bubble is 0.4R, To save space, other simulation no longer be listed.

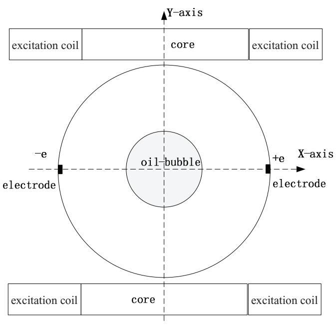


Fig. 1 Simulation model that oil bubble exists in the center of pipeline.

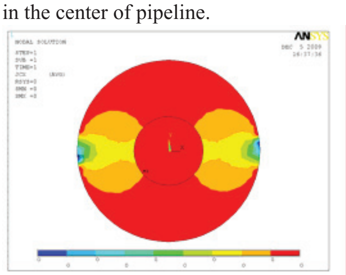


Fig. 2 the distribution of the virtual current in x direction with diameter 0.4R oil bubble in the fluid

Figure 3 shows the distribution of the virtual current in the x-axis direction and the distribution equipotential potential map of virtual current in x direction with diameter 0.4R oil bubble in the fluid. It is seen that oil bubble influenced the virtual current distribution actually, but impact analysis still can not be quantified, so the sensitivity(c) is introduced here to evaluate exactly.

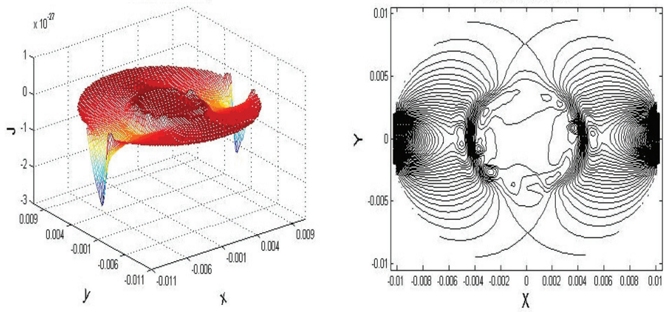


Fig. 3 The virtual current distribution with diameter 0.4R oil bubble

Figure 4 shows the analysis of sensitivity(c) at different diameters of the oil bubbles exists in fluid. The abscissa stands for the diameter of oil bubble, the vertical coordinates is sensitivity(c). According to the simulation diagram, the diameter of oil bubble is bigger, c is the larger. That is to say: when oil bubble locates certain position in the fluid, the larger the oil bubble is, the greater impact on the flowmeter will be.

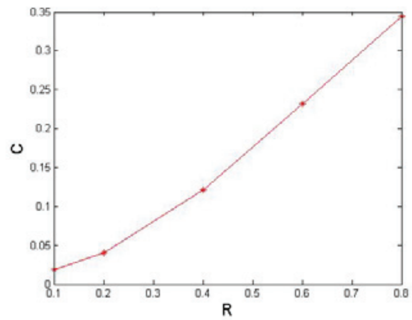


Fig. 4 the analysis of c at different diameters of the oil bubbles exist in fluid

In order to examine the changes of the virtual current, Figure 5 is shown the influence analysis of the virtual current with different diameters of oil bubbles in fluid. As shown in the figure, The abscissa stands for the diameter of oil bubble, the vertical axis is Jb/Jw, Jb/Jw is the ratio between the Jb and the Jw (Where Jb and Jw are the component of the virtual current in the x direction with oil bubbles and without bubbles in the fluid, respectively).It can be shown as: with the diameter of the oil bubble increases, the virtual current becomes smaller gradually. That is to say: The diameter of oil bubble smaller, the lesser influence on virtual current of flowmeter.

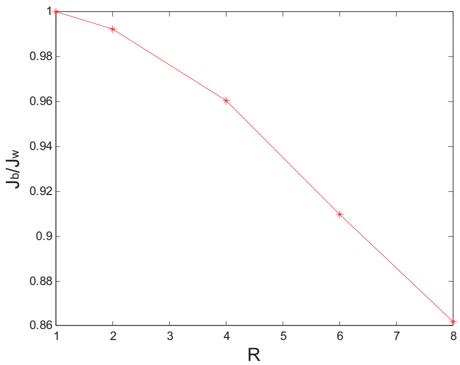
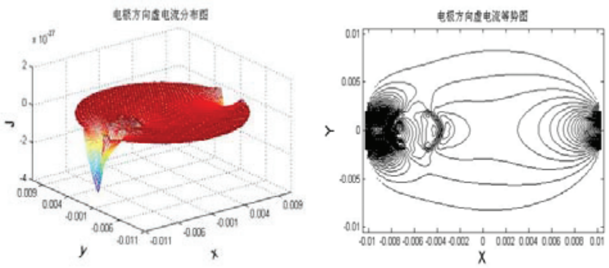


Fig. 5 the influence analysis of the virtual current with different diameters of oil bubbles in fluid

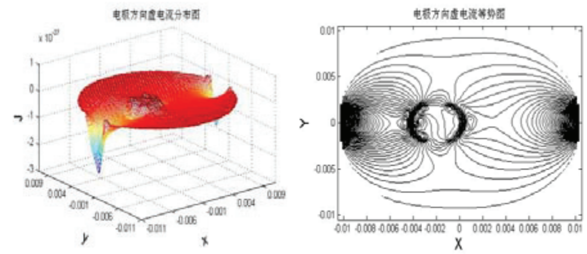
4 Analysis on Difference Position of Oil Bubble Impact on Virtual Current

The issue that how oil bubbles impact on the flowmeter if they have same size but different position is studied in this section. The diameter of oil bubbles is set 0.2R in the simulation of this section, which is locate at different position at cross section of measure area in x-axis and y-axis or in the line paralleled to it, and we can study how it impact on electromagnetic flow meter.

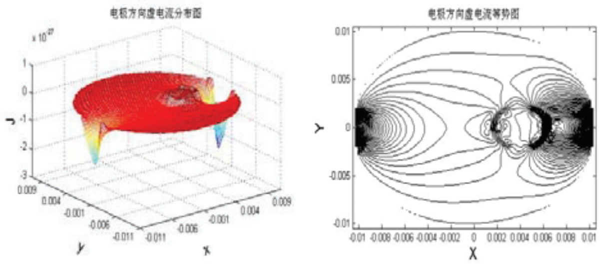
Figure 6 shows distribution and equipotential potential map of virtual current with oil bubble locate different position at x-axis of cross section. We have studied distribution and equipotential potential map of virtual current with oil bubble locate different position at y-axis of cross section in the simulation. To save space, only part of the simulation diagrams is listed. From the Figure 6 we can see: The distribution of virtual current is different while the oil bubble's position at x-axis is different. However, a numerical comparison can not be given yet. In order to obtain clear influence of virtual current distribution with different position of oil bubble. The sensitivity(c) is introduced here to evaluate exactly when oil bubbles have different position in x-axis and y-axis.



(1) The distribution of Virtual current when oil bubble is -0.6R at x-axis



(2) The distribution of Virtual current when oil bubble is -0.2R at x-axis



(3) The distribution of Virtual current when oil bubble is +0.4R at x-axis

Fig. 6 The distribution and equipotential potential map of Virtual current when oil bubble is different position at x-axis

Figure 7 shows the analysis of sensitivity(c) at different position along x-axis or in the line paralleled to x-axis at cross section with an oil bubble which the diameter is 0.2R in the fluid. Abscissa is position of x-axis at cross section, the vertical coordinates is sensitivity(c), and the legend shows the different position of y-axis. As shown in the simulation diagram, which indicates when the oil bubble closer to electrode, c increases rapidly, the impact of flow meter rapidly increase; and when diameter 0.2R oil bubble is at position 0(Coordinate origin) in the x-axis(y=0) or in the line paralleled to x-axis(y=0.2R,y=0.4R), the value of sensitivity(c) is the smallest in this line at x-axis or at the line paralleled to x-axis, That is say: the minimum impact of flow meter is the oil bubble located o at this line of x-axis or the line paralleled to x-axis.

Figure 8 shows the analysis of sensitivity(c) at different position along y-axis or in the line paralleled to y-axis at cross section with an oil bubble which the diameter is 0.2R in the fluid. Abscissa is position of y-axis at cross section, the vertical coordinates is sensitivity(c), and the legend shows the different position of x-axis. As shown in the simulation diagram, which indicates when diameter 0.2R oil bubble is at position 0(Coordinate origin) in the y-axis or in the line paralleled to y-axis, the value of sensitivity(c) is the largest in this line, that is the greater impact of flow meter is the oil bubble locate o in the this line. And the sensitivity(c) of the line which x is 0 is the larger then the line which x is 0.2R, the sensitivity(c) of the line which x is 0.2R is the larger then the line which x is 0.4R. That's because the center of y-axis(or the line paralleled to y-axis) is relatively closer to the electrode.

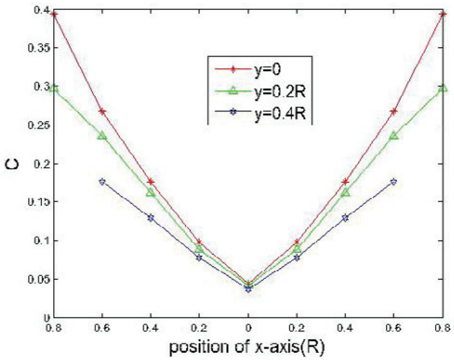


Fig. 7 the analysis of Sensitivity(c) with oil bubble different position in x-axis

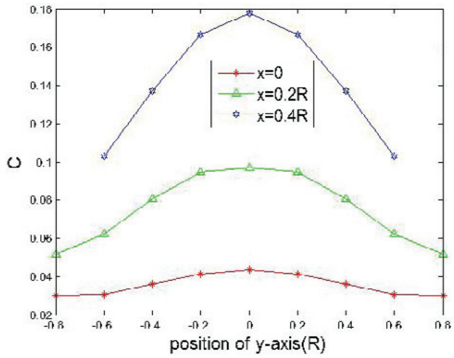


Fig. 8 the analysis of Sensitivity(c) with oil bubble different position in y-axis

Using the above method, we can get sensitivity(c) when oil bubble locates different position in cross-section of electromagnetic flowmete measure area, and then we can get the sensitivity (c) of all the cross-section of measure area. We have studied more sensitivity (c) of the electromagnetic flowmeter when the position of the oil bubble is different position which in the straight line paralleled to the x-axis and y-axis, and the simulation results similar to Figure 7 and Figure 8. From the a lot of simulation analysis, we can draw the conclusions as follow: if oil bubble is closer to the electrode at x-axis or at the line paralleled to the x-axis, the sensitivity(c) of flow meter is greater; if oil bubble at y-axis or at the line paralleled to the y-axis is closer to the x-axis (that is to say: closer to the electrode), the sensitivity(c) of flow meter is greater. Which provide reference for measurement of electromagnetic flow meter in two-phase flow of oil-water.

5 Conclusion

In this paper, a simulation model is established to study response characteristics of the flow meter in which a oil bubbles exist by using the finite element software ANSYS. The characteristic of a flow meter with different size oil bubble in the cross-section of measuring area is analyzed. Furthermore, different positions of oil bubble which in the cross-section of measuring area impact on the electromagnetic flow meter are analyzed. The work has given us a way to estimate the error of an electromagnetic flow meter in two-phase flow or multiphase flow; the conclusion provided a reference for electromagnetic flow meter measure two-phase flow of oil-water.

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